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Release of a Thinned Budworm-Infested Douglas-Fir/ Ponderosa Pine Stand

**Clinton E. Carlson
Robert D. Pfister
Leon J. Theroux
Carl E. Fiedler**

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THE AUTHORS

CLINTON E. CARLSON is research forester with the Forestry Sciences Laboratory in Missoula, MT. He earned his B.S. in forest science in 1964, M.S. in forestry in 1966, and Ph.D. in botany in 1978 from the University of Montana. From 1966 until 1979 he was plant pathologist with the Northern Region, USDA Forest Service, where he conducted field and laboratory studies on the effects of air pollutants on forest ecosystems. Since 1979 he has conducted research concerning the interrelationships between silvicultural practices and western spruce budworm for the Intermountain Research Station in Missoula.

ROBERT D. PFISTER is director of the Mission Oriented Research Program, Montana Forest and Conservation Experiment Station, at the University of Montana. His work involves research on basic ecological resources of forests and the integration of research information into management planning. Prior to his current assignment, he was principal plant ecologist with the Intermountain Forest and Range Experiment Station, USDA Forest Service, in Missoula, MT, where he was project leader of the forest ecosystems research work unit. He holds B.S. and M.S. degrees in forest management from Iowa State University and Oregon State University, respectively, and a Ph.D. in botany from Washington State University.

LEON J. THEROUX is biological technician with the Forestry Sciences Laboratory in Missoula, MT. He earned a B.S. in forestry in 1971 from the University of Montana. Since 1978 he has been involved in research concerning the effects of western spruce budworm on forests of the Northern Rocky Mountains and studies concerning factors influencing seed and cone development in western larch forests. Prior to his current assignment, he was involved in forest insect research at the Forestry Sciences Laboratory in Moscow, ID.

CARL E. FIEDLER is research forester with the Montana Forest and Conservation Experiment Station at the University of Montana, Missoula. His research activities include studies on regeneration and stand management in coniferous forests of the Central and Northern Rocky Mountains. Much of his work centers on the Lubrecht Experimental Forest near Missoula.

RESEARCH SUMMARY

Current and past defoliation by western spruce budworm (*Choristoneura occidentalis* Freeman) in an 80-year-old predominantly Douglas-fir (*Pseudotsuga menziesii* var. *glauca* [Beissn.] Franco) stand thinned to 14 by 14 feet was significantly lower than in a nearby untreated stand of similar age, species, and site conditions. Analysis of periodic radial growth ratios indicated that prior to thinning, Douglas-fir had been heavily defoliated by budworm and growth was seriously depressed. Following thinning, the host leave trees developed dense crowns and 10-year radial growth increased an average of 57 percent; meanwhile, radial growth of nonhost ponderosa pine (*Pinus ponderosa* Dougl.) increased 38 percent. Several hypotheses individually or collectively may explain this effect of thinning on budworm defoliation. The thinning may have caused increased mortality of budworm larval stages, the trees simply released and outgrew the insect, or the defensive chemistry of leave trees was enhanced. Radial growth of ponderosa pine accelerated in both the thinned and unthinned stands prior to thinning. This prethinning release of pine probably was in response to the defoliation, and reduced competition, of Douglas-fir.

ACKNOWLEDGMENTS

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INTRODUCTION

Douglas-fir (*Pseudotsuga menziesii* var. *glauca* [Beissn.] Franco) forests of the Northern Rocky Mountains are vulnerable to the western spruce budworm, *Choristoneura occidentalis* Freeman, (Johnson and Denton 1975). Certain site and stand factors, such as stand density, are hypothesized to influence vulnerability (Carlson and others in press). While studying densities of mixed conifer stands in western Montana, we noted striking contrasts in defoliation between two adjacent stands; these stands were within an active budworm outbreak. Douglas-fir in one stand, thinned about 10 years previously, looked relatively healthy, whereas firs in the nearby unthinned stand were heavily defoliated. Substantial reduction of radial growth of host trees usually is associated with outbreaks of budworm (Williams 1966; Johnson and Denton 1975; Brubaker and Greene 1978; Alfaro and others 1982). We therefore questioned (1) whether defoliation had depressed radial stem growth of Douglas-fir before thinning and (2) whether radial growth had recovered since the thinning. This paper presents the results of a study concerning relationships of current budworm defoliation and of periodic radial increment between the thinned stand and the unthinned stand.

Western spruce budworm is a serious pest of forests in western North America (Johnson and Denton 1975; Fellin and Dewey 1982), particularly in unmanaged stands (Carlson and others in press). Although this defoliating insect does not cause significant impact in most even-aged seral conifer stands less than 20 years old, host stands older than 20 years at times are damaged (Schmidt and others 1983). Intermediate-aged (20 to 80 years) Douglas-fir/ponderosa pine (*Pinus ponderosa* Dougl.) stands have developed since the early 1900's, probably due to increasingly effective fire suppression (Dickman 1978; Arno 1980). Selective harvesting practices also contributed to the establishment and development of these stands (Schmidt and others 1983). Intermediate-age stands now occupy many thousands of acres in the Northern Rocky Mountains and appear to be highly suitable habitat for budworm.

Reducing stand density and creating unistoried conditions in immature Douglas-fir stands may decrease susceptibility to western spruce budworm (Carlson and others in press), but this hypothesis has not been extensively field tested. In unthinned natural host stands, susceptibility to western spruce budworm was found to increase as density of host species increased (Fauss and Pierce 1969; Despain 1981; Carlson and Theroux 1982). Similarly, increasing crown closure (that is, density) of balsam fir (*Abies balsamea* [L.] Mill.) in Maine resulted in better survival of spring-dispersing larvae (Kemp and Simmons 1979); in Quebec, defoliation of balsam fir increased as the basal area and number of stems of fir increased but decreased as the percentage of nonhost (hardwoods) increased (Crook and others 1979).

METHODS

Two stands, one thinned, the other unthinned, were selected for study (fig. 1) about 30 miles east of Missoula, MT, in the Blackfoot River drainage. Habitat type (Pfister and others 1977) in both stands was *Pseudotsuga menziesii/Symphoricarpos albus* h.t., with minor inclusions of *Pseudotsuga menziesii/Vaccinium caespitosum* h.t. The thinned stand (160 acres), on State land near the northern border of Lubrecht Experimental Forest, had been treated in 1973. Sixty percent of the volume removed was Douglas-fir, 35 percent ponderosa pine, and 5 percent western larch (*Larix occidentalis* Nutt.). The treatment was a best-tree thinning with removal of a few old (200+ years) veteran overstory Douglas-fir and ponderosa pine, leaving a mixed stand of dominant and codominant conifers with species composition in approximately the same proportion as the volume removed. Currently there are about 214 trees per acre, equivalent to a 14- by 14-foot spacing (table 1).

The unthinned stand (200 acres) is located about one-half mile southwest of the thinned stand on similar aspect (NW), elevation (4,000 feet m.s.l.), and slope (5 to 10 percent) as the thinned stand. The thinned stand is 77 years old, the unthinned is 86. In all respects, except for the thinning and slight age difference, the two stands are similar. The percentage of Douglas-fir and

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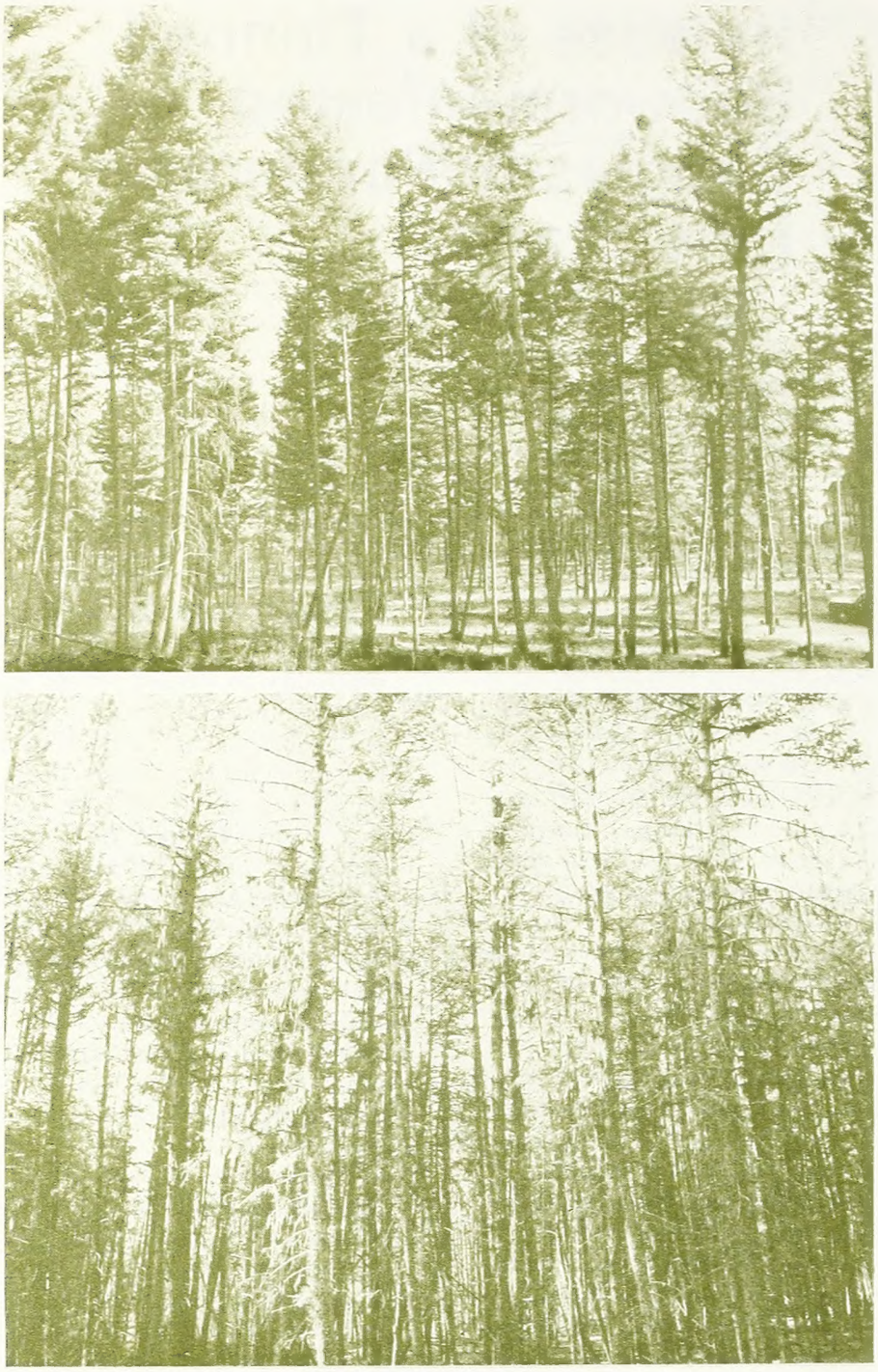

Figure 1.—Top: thinned stand thinned to 14 by 14 feet, average spacing; bottom: unthinned stand.

Table 1.—Current stand density and average diameter by species for the thinned and unthinned stands, Lubrecht Experimental Forest

Species	Basal area				Number of trees				Mean d.b.h.	
	Thinned		Unthinned		Thinned		Unthinned		Thinned	Unthinned
	Ft²/ acre	*Pct*	*Ft²/ acre*	*Pct*	*No./ acre*	*Pct*	*No./ acre*	*Pct*	*Inches*	
Douglas-fir	81.7	67	105.3	61	167	78	460	63	9.5	6.5
Ponderosa pine	39.7	33	67.0	39	47	22	273	37	12.5	6.7
Total	121.4		172.3		214		733			

ponderosa pine in the unthinned stand is 61 and 39, respectively, similar to the thinned stand (table 1).

Three circular 0.10-acre plots were systematically located in each stand. Within each plot in the thinned stand, tree density, species, d.b.h., height, crown ratios, and budworm defoliation were recorded. On the control plots, tree density and species composition were based on all trees present on the plot, whereas d.b.h., height, crown ratios, and defoliation were recorded for those trees that would have been retained had the plot been thinned.

A whole-crown ocular estimate, which included all crown levels and ages of foliage, of budworm defoliation was made and classed for each host tree. The classes were:

Rating class	Percent defoliation
1	0–25
2	26–50
3	51–75
4	76–100

This rating was done from the ground—no branch samples were taken.

In addition to the whole-tree estimate, current defoliation was assessed on four midcrown branches of each of three trees on each plot. Sample trees had to be climbed because the branch sampling was nondestructive (fig. 2). Four branches were permanently tagged for future reference, and defoliation on each branch was estimated and recorded according to the method of Carlson and others (1982). Twenty-five new shoots were observed and each was rated as follows:

Rating class	Percent defoliation
0	0
1	1–25
2	26–50
3	51–75
4	76–99
5	100

Classes 0 and 5 were included here because, unlike the ground-based estimates of whole-tree defoliation, it was possible to distinguish 0 and 100 percent defoliation.

Increment cores were taken to assess the response of radial stem growth to thinning, budworm defoliation, or a combination of the two. Two 0.197-inch-diameter cores were extracted at d.b.h. from opposite sides of each sample tree parallel to the topographic contour. Five sample trees of each species, Douglas-fir and ponderosa pine, were randomly selected from the list of plot trees. If five trees were not present, then the nearest tree similar to the plot trees, but outside the plot, was selected. Cores were labeled and sealed in plastic straws to prevent moisture loss, returned to the laboratory, and frozen until measurements were made.

In the laboratory, annual increment was measured to the nearest 0.003 inch and recorded for each core, using a Bannister Incremental Measuring Machine. Annual

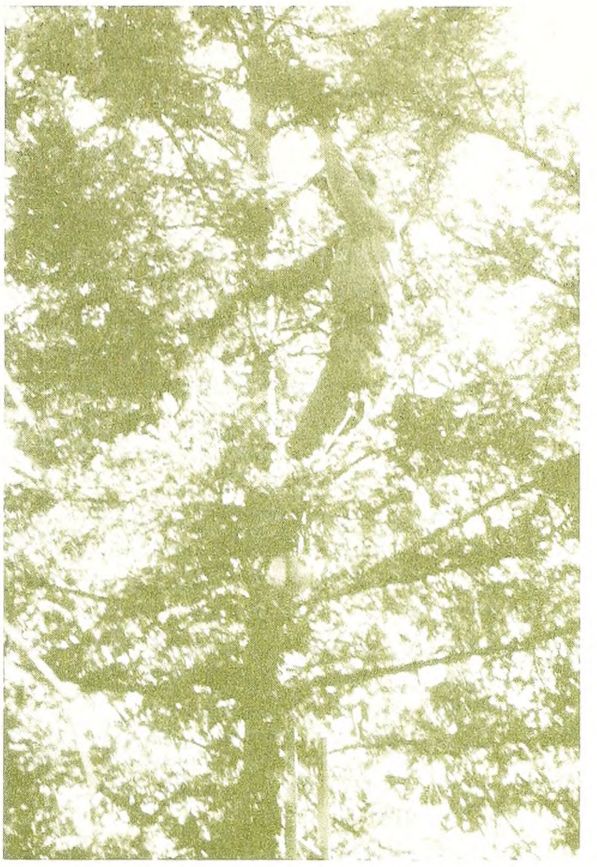

Figure 2.—Inspecting midcrown branches for defoliation caused by budworm.

increment was averaged by year for the two cores from a sample tree and this average value was used in subsequent analyses. Our null hypotheses were:

1. Defoliation (whole-tree and current-measured) on Douglas-fir was not different between the thinned and unthinned stand.
2. Radial growth of Douglas-fir (a) has not changed since thinning, (b) is not different from radial growth of ponderosa pine, and (c) is not different between the thinned and unthinned stands.

Four variables were selected to test these hypotheses, using the "t" statistic for an unpaired design (Sokal and Rohlf 1969). Whole-tree defoliation (ground-based visual estimate) and measured current defoliation (four-branch midcrown sample) on Douglas-fir were tested between stands. Two growth ratios were computed—one to represent growth since thinning, the other to depict growth prior to thinning:

Ratio 1—Radial growth since thinning ÷ 10-year radial growth just prior to thinning.

Ratio 2—10-year radial growth immediately prior to the date of thinning ÷ 10-year radial growth 11 to 20 years previous to thinning.

These radial growth ratios were tested (1) between treatments (thinned and unthinned) by species, (2) between species (Douglas-fir and ponderosa pine) by treatment, and (3) between growth periods (before and after thinning) by treatment by species.

Finally, a graphical analysis of radial increment to determine past budworm activity in the stands was done according to procedures developed previously (Carlson and McCaughey 1982).

RESULTS AND DISCUSSION

Defoliation of Douglas-fir was much lower in the thinned stand than in the unthinned stand (table 2). Whole-tree defoliation (ground-based estimate) was only 15 percent in the thinned stand, whereas the unthinned stand was 43 percent, and the difference was significant at $p \leq 0.05$. Similarly, measured defoliation on current-year midcrown shoots in the thinned stand was 44 percent, significantly lower ($p \leq 0.05$) than in the unthinned where defoliation averaged 66 percent.

These two different estimates of defoliation differ substantially in magnitude but are similar to each other in trend between the stands. It is not surprising that the magnitudes of the estimates are different because they estimate two different "types" of defoliation. The whole-tree estimate reflects the observer's interpretation of defoliation over all the needle age classes and crown levels in a tree, whereas the shoot counts reflect a more accurate estimate but only on current year's needles from midcrown. Thus, the whole-tree estimate likely is more appropriate for long-term evaluation because it reflects the current condition of the whole crown as influenced by several years of budworm feeding and probably closely reflects diameter growth. A detailed analysis between shoot count and ocular methods of estimating defoliation on balsam fir in eastern North America showed that plot means of ocular estimates were lower than shoot count estimates from the same trees (MacLean and Lidstone 1982), similar to our observations at Lubrecht. MacLean and Lidstone (1982) concluded that ground-based ocular methods gave reliable estimates of budworm defoliation.

Complementing this reduced defoliation in the thinned stand, radial growth of both species accelerated in response to thinning. In the unthinned stand, annual radial growth of Douglas-fir paralleled that of ponderosa pine between 1935 and 1966 (fig. 3). In 1967, however, Douglas-fir radial growth declined, presumably in response to the feeding pressure by budworm, whereas ponderosa pine increased in response to the "biological thinning" (defoliation) done by the insect.

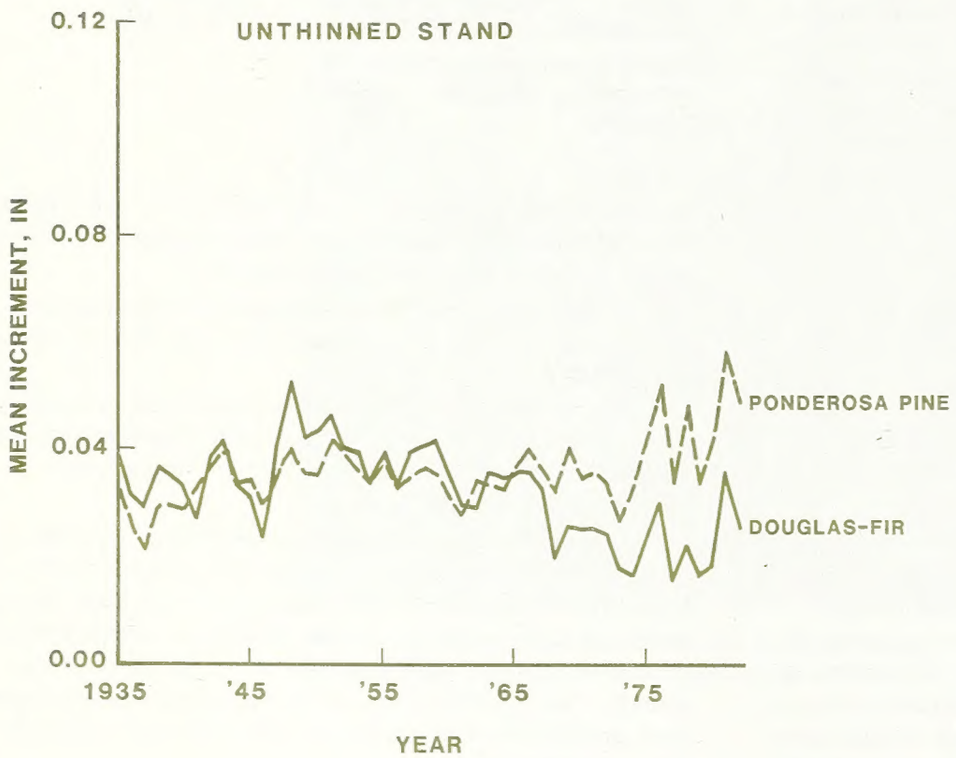

Figure 3.—Mean annual radial increment of Douglas-fir and ponderosa pine in the unthinned stand. Mean increment was similar for both species until the late 1950's when the budworm infestation became heavy.

Table 2.—Comparison of mean defoliation (percent) of Douglas-fir trees between the thinned and unthinned stands, Lubrecht Experimental Forest

Variable	Stand		Statistics	
	Thinned	Unthinned	"t"	Prob.
Whole-tree defoliation	15	43	−8.23	0
Measured current defoliation	44	66	−2.72	0.016

Radial growth of Douglas-fir was similar to that of pine in the thinned stand prior to the thinning until about 1960 (fig. 4). Radial increment of both species increased between 1935 and 1952 but decreased from 1952 to 1960. Subsequently, the trend for fir diverged from that of pine from 1960 until 1973, about the date of thinning. Radial increment of both species then increased from 1973 until present (1983). Unlike the unthinned (fig. 3), however, pine in the thinned stand (fig. 4) maintained much better annual increment (about 0.07 inch per year) than the fir (about 0.04 inch per year).

The general presence of budworm in the two stands is reflected in the radial growth of Douglas-fir as analyzed according to the methods of Carlson and McCaughey (1982). Budworm appears to have impacted the fir about 1960, indicated by the divergence of the host curve (fir) from the nonhost (fig. 5). The cumulative curve for Douglas-fir also dropped sharply in 1927, but because the same inflection at the same date occurred for pine, that drop is attributed to factors other than budworm.

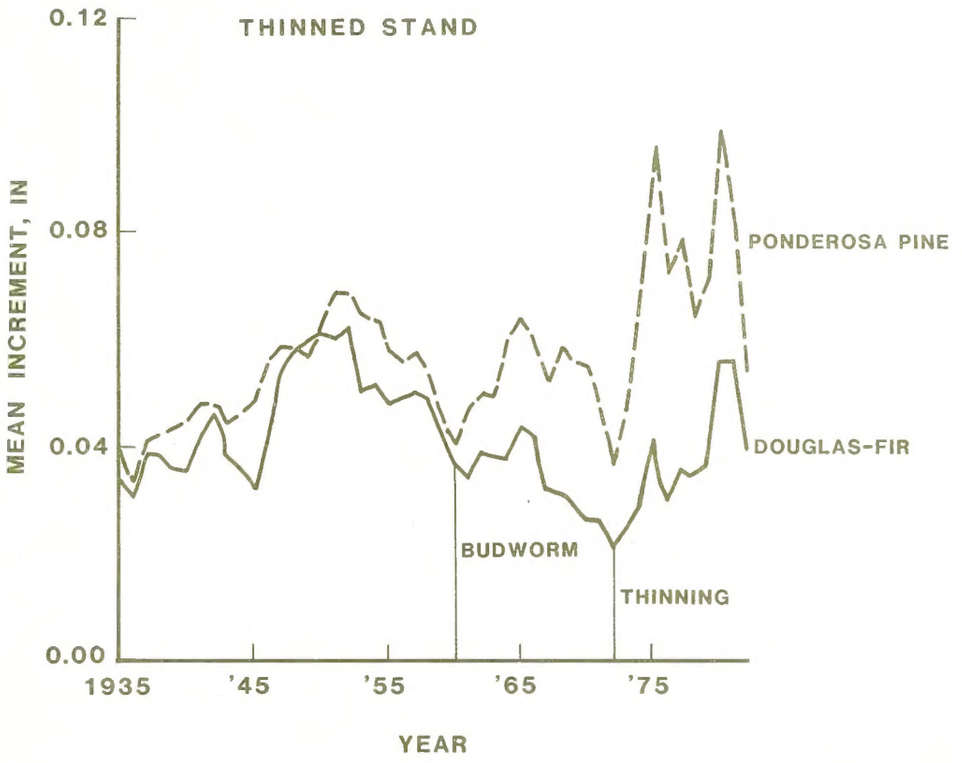

Figure 4.—Mean annual radial increment of Douglas-fir and ponderosa pine in the thinned stand. The budworm was heavy during the late 1950's through the 1970's, and the pine released in the late 1960's, presumably due to the biological thinning done by the insect on the Douglas-fir.

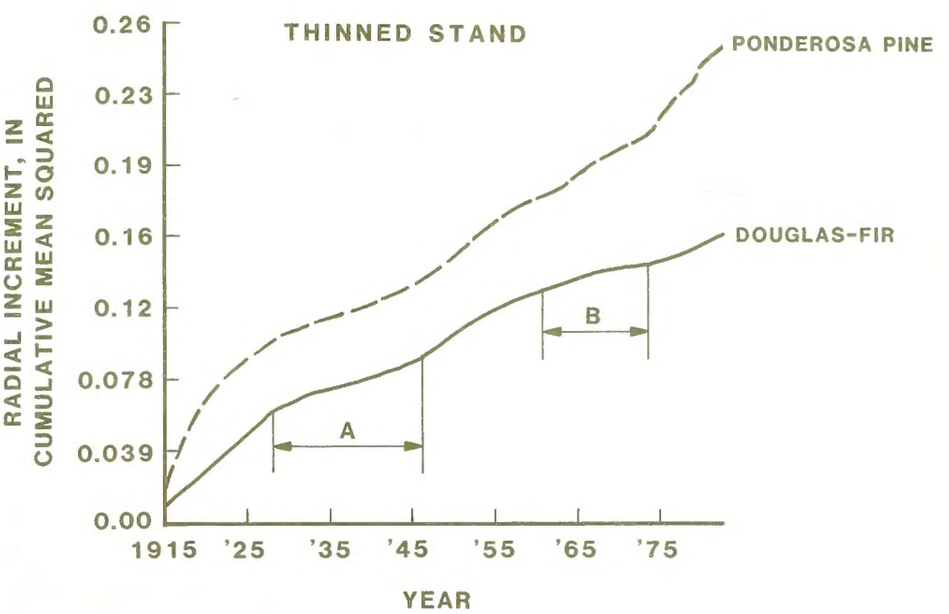

Figure 5.—Cumulative mean squared radial increment of Douglas-fir and ponderosa pine in the thinned stand. Budworm probably caused the deflection of the Douglas-fir curve from 1960 to 1973 (B), whereas other factors, such as drought and/or stand density, caused the deflection beginning in 1927 (A). A similar trend was observed for the unthinned stand.

The interpretation of a budworm-induced impact on fir between 1960 and 1983 in the unthinned stand appears to be reasonable and is corroborated by yearly observations of defoliation at Lubrecht (Fellin 1984).

The relative growth responses (growth ratios) of both Douglas-fir and ponderosa pine demonstrate the significance of the thinning and the influence of budworm (fig. 6). Current relative radial growth (ratio 1) of Douglas-fir in the thinned stand was significantly greater than in the unthinned stand ($p \leq 0.05$); ponderosa pine had a modest but nonsignificant ($p \leq 0.05$) increase (table 3). Prior to thinning (ratio 2), relative growth of Douglas-fir actually was slightly greater in the unthinned stand than in the thinned stand, but the difference was barely significant ($p \leq 0.05$), whereas ponderosa pine growth was not statistically different between the stands.

Relative radial stem growth (ratios 1 and 2) of Douglas-fir was significantly less ($p \leq 0.05$) than ponderosa pine in the unthinned stand (table 4). Relative growth of fir also was significantly less ($p \leq 0.05$) than pine in the thinned stand prior to treatment (ratio 2). Nevertheless, posttreatment relative growth (ratio 1) of fir in the thinned stand was not different from the relative growth of pine; here Douglas-fir radial growth accelerated and, in a relative sense, nearly equaled that of pine.

Both Douglas-fir and ponderosa pine responded dramatically to thinning. Radial growth rates of both species in the thinned stand after thinning (ratio 1) were significantly greater ($p \leq 0.05$) than before thinning (ratio 2) (table 5). Radial growth of Douglas-fir increased 57 percent, whereas pine increased 38 percent. In the unthinned stand, however, growth of Douglas-fir did not change between the periods (ratio 1 vs. ratio 2, $p \leq 0.05$), whereas growth of ponderosa pine increased significantly ($p \leq 0.05$) during the most recent period.

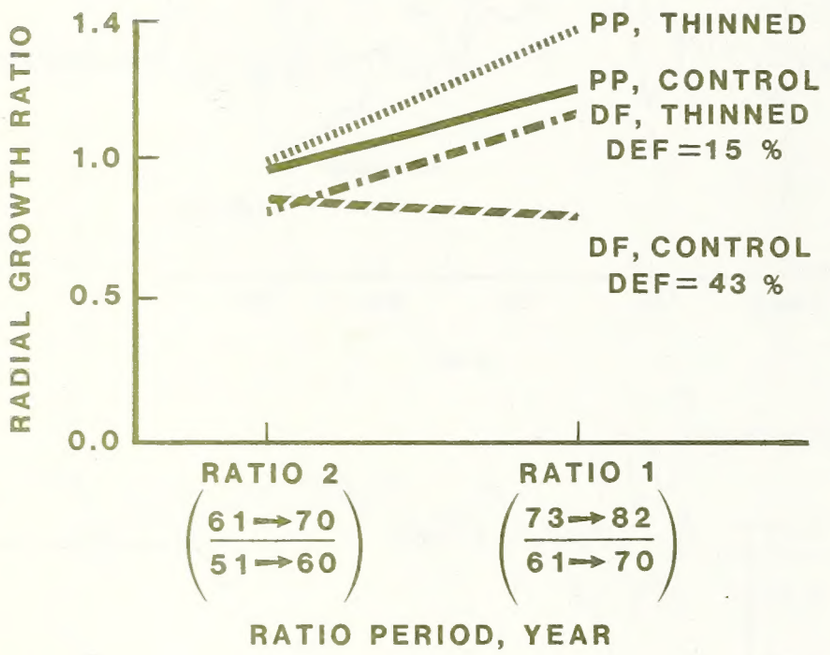

Figure 6.—Influence of thinning on radial growth of ponderosa pine and of Douglas-fir infested with western spruce budworm. Thinning relieved the budworm pressure on Douglas-fir, resulting in accelerated radial growth. The nonhost ponderosa pine exhibited accelerated radial growth before thinning and in the unthinned stand, demonstrating the "biological thinning" induced by the budworm. PP = ponderosa pine; DF = Douglas-fir; DEF = defoliation; 61 = 1961; 70 = 1970.

Table 3.—Comparison of radial growth ratios by species between the thinned and unthinned stands, Lubrecht Experimental Forest

	Thinned	Unthinned	"t"	Prob.
Ratio 1 DF	1.13	0.74	3.10	0.004
PP	1.35	1.22	1.00	.329
Ratio 2 DF	.72	.80	−2.08	.045
PP	.98	.98	0	.998

Table 4.—Comparison of radial growth ratios between species in the thinned and unthinned stands, Lubrecht Experimental Forest

	Thinned				Unthinned			
	DF[1]	PP[1]	"t"	Prob.	DF	PP	"t"	Prob.
Ratio 1	1.13	1.35	−1.49	0.146	0.74	1.22	−4.35	0
Ratio 2	.72	.98	−4.11	0	.80	.98	−3.28	0.003

[1]DF = Douglas-fir; PP = ponderosa pine.

Table 5.—Comparison of pre- and posttreatment radial growth ratios by species in the thinned and unthinned stands, Lubrecht Experimental Forest

		Ratio 2 (before thinning)	Ratio 1 (after thinning)	"t"	Prob.
Thinned stand	DF[1]	0.72	1.13	3.96	0
	PP[1]	.98	1.35	3.04	0.005
Unthinned stand	DF	.74	.80	−.88	.383
	PP	.98	1.22	2.20	.038

[1]DF = Douglas-fir; PP = ponderosa pine.

The poor periodic radial increment of Douglas-fir in the unthinned stand and in the thinned stand prior to thinning is attributed to a combination of stand density and defoliation by western spruce budworm. The insect has been present at relatively high levels (obvious defoliation on Douglas-fir) in the vicinity of the study area since the late 1950's (Fellin 1984), and we have every reason to believe that fir in the thinned stand and unthinned stand was equally affected by budworm. Without budworm, we would expect the relative growth of fir to be similar to the pine, a notion supported by the radial growth patterns between 1935 and 1960 (figs. 3, 4).

Thinning appeared to alleviate budworm pressure; defoliation was much reduced in the thinned stand and residual trees, both host and nonhost accelerated in radial stem growth. We do not know whether absolute budworm populations were reduced in the thinned stand, but we suspect so. Thinning, however, may have stimulated the crowns of the residual Douglas-fir, resulting in production of high amounts of foliage. Given a constant budworm population per tree, the **relative** budworm population per tree (budworms per unit foliage) in the thinned stand would have decreased, resulting in a lower defoliation percentage. Alternatively, opening the stand probably would increase dispersal losses of the larval stages, also resulting in lower defoliation.

Furthermore, the defensive chemistry of fir may have been enhanced by the thinning. Cates and others (1983) showed that terpene profiles of Douglas-fir are altered by stress. As moisture stress increased, bornyl acetate decreased, causing more favorable substrate for budworm. Presumably, the thinning at Lubrecht decreased tree stress, augmented the defensive chemistry, and reduced susceptibility of the Douglas-fir to western spruce budworm.

Whatever the reasons, radial growth of Douglas-fir in the thinned stand recovered and nearly equaled the thinning response of the nonhost ponderosa pine. Given that the stands are relatively old for thinning (about 80 years), this response should be encouraging to land managers because we would expect similar or better responses in younger stands.

Ponderosa pine apparently benefited from the budworm outbreak. In the unthinned stand, current 10-year periodic radial increment increased dramatically. This accelerated growth of pine in the unthinned stand indicates that the budworm was acting as a biological thinning agent. This presumed natural "thinning" effect has been observed elsewhere for western spruce budworm (Carlson and McCaughey 1982), but this study presents more definitive data supporting such an effect.

Although this study shows the influence of thinning on budworm defoliation and host tree growth, some caution is advised. This was a case study between two stands; there was no replication to include other thinned and unthinned stands. Furthermore, the sample size was small. Thus, the results may be applicable only to the stands from which the data were collected. In our opinion, however, the results are broadly applicable. Based on the literature, the biology of the budworm and its hosts, and data from this study, we conclude that thinning the 80-year-old stand reduced the pressure of budworm on Douglas-fir and significantly improved the growth of both ponderosa pine and fir. At least, this is a strong working hypothesis that should be valuable for researchers and land managers until further testing is possible.

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Eighty-year-old Douglas-fir (*Pseudotsuga menziesii*) in a thinned stand of mixed conifers in western Montana showed less impact due to defoliation by western spruce budworm (*Choristoneura occidentalis*) than firs in an adjacent unthinned stand. Radial growth of thinned fir increased 57 percent; ponderosa pine (*Pinus ponderosa*), 38 percent; whereas unthinned fir grew very slowly. In both stands, radial growth of pine increased substantially, even before thinning, probably because defoliation weakened the competing fir. Thinning may reduce budworm impact by increasing larval mortality, enhancing host tree growth, or stimulating the tree's defensive chemistry.

KEYWORDS: *Choristoneura*, budworm, silviculture, thinning, stand density, budworm impact

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